

SUMMARY OF THE ATMOSPHERIC CHEMISTRY INSTRUMENT VALIDATION RESULTS AS PRESENTED AT THE ACVE-3 WORKSHOP

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ABSTRACT

This paper summarises the results of the validation of the Envisat atmospheric instruments as presented by the validation teams during the ACVE-3 workshop.

1. OVERVIEW

The third workshop on the Atmospheric Chemistry Validation of ENVISAT (ACVE-3) was held at ESA-ESRIN on 4 - 7 December 2006. This paper summarises the results of validation work, carried out since the ACVE-2 workshop in May 2004, for the three ENVISAT atmospheric instruments: SCIAMACHY, MIPAS and GOMOS as presented during the ACVE-3.

The target of the workshop is to review the quality of the Level 1b and Level 2 products based on independent geophysical correlative measurements. The results provide the user community with a verifiable estimate on the individual datasets, both provided by ESA and the Science Community. In addition ESA will use the recommendations for future processor developments and processing decisions.

This summary has two parts: firstly, issues that are common to all three instruments are presented and then results relating to the individual instruments are discussed in more detail. The ACVE-3 provided an important opportunity for scientists involved in validation work to present their findings to a wider ACVT community and to ESA in particular. It is important to present to ESA the results of validation and to define validation requirements in the short term, throughout the ENVISAT mission life and even beyond.

The ACVE-3 workshop was like the ACVE-1 [1] and ACVE-2 [2] an undoubted success involving a total of 70 participants, 66 oral presentations and 12 posters. The number of atmospheric products reviewed was

equally impressive: 20 from SCIAMACHY, 7 from MIPAS and 5 from GOMOS.

All three instruments continue to operate well, although GOMOS and MIPAS operate with certain operational limitations.

Full details of the validation results summarized in this paper can be found in the individual contributions in this proceedings.

2. COMMON ISSUES

2.1 Introduction

The following sections summarise various issues that were raised in presentations and in subsequent discussion. They are not specific to any particular atmospheric chemistry instrument.

2.2 Validation Datasets

For product validation a well defined subset of the overall dataset needs to be carefully selected to allow the validation teams to assess the quality of the products. In principle it is desirable to have sufficient data to enable the comparison over at least a complete year to be able to analyse seasonal effects and instrumental trends. However, in order to limit the validation progress not by the effort of reprocessing, the selection of data will be based on the recommendation of the ACVT towards ESA. This situation requires careful planning and ESA will continue to manage the resources available in the best manner possible. Continuous validation on the complete operational and reprocessed dataset provides important results regarding seasonal, inter-annual and instrumental trends in the product quality.

The validation datasets available are listed below.

2.2.1 MIPAS Full resolution (FR) mode (launch - March 2004)

- Level 1b and level 2 reprocessing with IPF version 4.61 and 4.62 has been finalised.
- Due to an IPF anomaly Level 2 data processed with IPF 4.62 should be used with care. Known affected datasets have been reprocessed.
- If available, IPF version 4.61 Level 2 should be used.
- Level 1b and Level 2 data are on-line at D-PAC.

2.2.2 MIPAS Reduced resolution (RR17) mode with 17 sweeps (09-22 Aug 2004, 16-17 Sept 2004)

- Level 1b and level 2 reprocessing with IPF version 4.65 has been finalized.
- Level 1b and Level 2 data are on-line at D-PAC.

2.2.3 MIPAS Reduced resolution (RR27) mode with 27 sweeps (10 Jan 2005 -present)

- Level 1b processing with IPF version 4.65.
- Level 1b data is available on-line at D-PAC

2.2.4 MIPAS Reduced resolution (RR27) mode with 27 sweeps - Validation Dataset

The data for this mode has been processed on a best effort basis with the prototype processors.

- Level 1b processing with the prototype processor MIGSP corresponding to upcoming IPF 5.xx.
- Level 2 processing with the prototype processor ML2PP corresponding to upcoming IPF 5.xx.
- Level 1b and Level 2 validation data distribution by D-PAC FTP server as soon as the data is available.

Only a limited data set was expected to be processed covering the major campaigns executed for the above mentioned mission scenario. There was also a small number of validation data for the Full Resolution

mission to be processed with the prototype processors. It was the intention to have the data set available in time for the ACVE-3 workshop, but due to limited resources no RR27 Level 2 processed by ESA was available. Some first results from processors developed at different institutes were presented during the workshop.

As the dataset is processed with the prototype processor minor differences to the operational processor IPF 5.xx might be observed.

2.2.5 GOMOS

- Reprocessed data processed with Prototype GOPR 6.0cf at ACRI from 26/07/2002 to 04/07/2006 (except for some outstanding Level 0 files) is available.
- IPF 5.00 products since 03/07/2006
- Level 1b data can be requested via Eohelp@esa.int
- Level 2 data is on-line at D-PAC.

As the dataset is processed with the prototype processor minor differences to the operational processor IPF 5.00 might be observed.

2.2.6 SCIAMACHY

Reprocessing of the validation data set for the ACVT members has been prepared.

- Level 1b processing with IPF version 6.02
- Level 2 processing with the Off-Line processor Version 3.00.
- Level 1b and Level 2 validation data are available on-line at D-PAC.

2.3 Changes with respect to previous processor versions

Please consult the presentation of Thorsten Fehr on "The ENVISAT Atmospheric Chemistry Mission: status and performance" given at the Atmospheric Science Conference, 8-12 May 2006, ESA ESRIN, Frascati, for specific information on the major processor related changes [3]. Details on the historical instrument performance and processor evolution can be found in the (bi-) monthly reports as produced by the Data Quality and Algorithm Management Office at ESA ESRIN. These reports are available at the Envisat

related part of the Product Control Service website (<http://earth.esa.int/pcs/envisat/>). Please follow the link to a specific instrument on the left hand side menu, select reports, and then select the type of report on the right hand side menu.

2.4 Platform Pointing Accuracy

The extraction of species profiles from limb sounding instruments depends on the platform pointing direction being known to a high accuracy. Since December 2003, the pointing accuracy of Envisat has improved substantially; however, some excursions still persist, affecting in particular SCIAMACHY and MIPAS limb-sounding observations. Envisat now exceeds its design specification and achieves pointing accuracy around 1km; although a pointing accuracy within 150m has been suggested as a more appropriate scientific requirement. Investigations on the pointing performance of the instruments are ongoing with the support of the science community.

2.5 Cross-comparison Between Envisat Instruments

Validation activities so far have involved products from Envisat instruments being compared with equivalent data from other instruments. Given that the validation of atmospheric instruments onboard Envisat has become more advanced, it is now considered appropriate to cross-compare products from SCIAMACHY, MIPAS and GOMOS. The need to monitor measurement coincidence in terms of time and space will continue to be important, given the different viewing methods and geometries involved.

3. MIPAS Validation Results

The full resolution (FR) measurements from July 2002 to March 2004 and processed with the operational processors IPF 4.61 and 4.62 are discussed in section 3.1 and 3.2 Some preliminary results of Reduced Resolution (RR27) Validation Dataset are given in section 3.3.

3.1 MIPAS FR Level-1b Processing IPF v4.61/v.462

The Level-1b processor works well and is very stable. The Level-1b data is of high quality. The instrument characterisation has been performed. The NESR is stable and well within requirements. The detector response as a function of incident photon flux has been characterised and parameterised on ground. In flight measurements have been used to determine new parameters. The comparison between on-ground and in-flight parameters shows small radiometric

differences in the calibrated spectra, below 2 % in most situations, but the non-linearity correction seems to be the most critical issue and characterisation work is still in progress. LOS calibration needs to be improved, but also depends on the pointing accuracy of the platform. The found discrepancy in the LOS calibration could be explained by an uncorrected roll angle, which is currently under investigation.

3.2 MIPAS FR Operational Products IPF v4.61/v4.62

Level-2 processing software is based on the Optimised Retrieval Model (ORM) scientific prototype using a non-linear least-square fit (Gauss-Newton method modified according to the Levenberg-Marquardt criterion), a global fit of the limb sequence, sequential retrieval of species, and it uses micro windows. The MIPAS Level 2 operational products are:

- Tangent pressures;
- temperature profile;
- VMR profiles of H₂O, O₃, HNO₃, CH₄, N₂O and NO₂

The results of validation show that the MIPAS data is generally of good quality and a consistent dataset is available.

The following products have undergone validation (for details see papers in this proceedings):

Temperature The found bias between MIPAS and correlative data is consistent with the error estimates produced by the University of Oxford. Some larger discrepancies in Latitude Bands were observed but it is not clear at this moment if this is due to errors in MIPAS or different systematic errors of the correlative measurements. The standard deviation was larger than estimated by a factor 2-3, the origin is yet unclear. A possible explanation could be related to the fact that the temperature and smoothing errors not taken into account for many comparisons.

O₃ A high bias in the upper part of the stratosphere with respect to HALOE was observed, but different results were found with other satellite and lidar observations. It was suggested that the spectroscopy database for the HALOE

dataset could be the cause of this difference. In the lower stratosphere a positive bias was shown, which is most likely to be caused by the large atmospheric variability in that region. Also an influence from the pt retrieval was suggested. Discrepancies are also due to undetected clouds.

H ₂ O	Between 100-10 hPa no bias was found, above 10 hPa a positive bias of 10% was shown. In the tropopause region a low bias and some oscillations were observed.
N ₂ O	The intercomparison with FTIR measurements showed that there is no bias present in the MIPAS results.
CH ₄	In the lower stratosphere a difference of 15% at 15 km was reported. The agreement for partial columns is within 10%.
HNO ₃	No bias has been identified. The spectroscopy has been improved in the FTIR ground based measurements, resulting in a improved agreement. The deviation found with respect to ODIN is most likely not due to the MIPAS data quality.
NO ₂	Strong diurnal variation in this species makes validation a challenging task and indeed there are deviations found between measurements from UV/VIS and IR ground based instruments. The comparison with balloon data showed no bias between 25 and 35 km. The intercomparison with other satellite measurements (mainly occultations) leads to very diverse results, probably induced by the strong diurnal variation.

3.3 MIPAS RR27 Validation Dataset

Around October 2003 the Interferometer Mirror Speed Error Anomalies started to increase significantly and in March 2004 the so-called instrument critical launch lock problem occurred. To avoid the increase of the speed anomalies it was recommended to reduce the MIPAS duty cycle from 100% to around 35 to 45% (raised to 50% on 10/12/2006). To avoid the launch lock problem the maximum mirror distance was changed from 20 to 8.2cm. As a result the MIPAS spectral grid was changed with the band lower and higher limits remaining the same, but with a new

spacing of 0.0625 cm⁻¹ instead of 0.025 cm⁻¹, resulting in a reduced wavelength resolution (RR mode). The nominal measurement scenario in this RR mode versus the old FR mode is:

FR Scan 17 Altitudes, with a minimum tangent altitude of 6 km.

RR Scan 27 Altitudes, with “floating altitudes”, the minimum tangent altitude is equal to 12km – 7km*cos(90° – |tangent point latitude|)

Also the spatial coverage in one orbit changed from ~72 scans in FR mode to ~112 scans in RR mode.

In order to cope with the ill-conditioning of the Level 2 retrieval due to a measurement and retrieval grid finer than the IFOV (in troposphere and low stratosphere) an a-posteriori Tikhonov regularization was introduced in the Level 2 retrieval. The regularization parameter is analytically determined using the error consistency method. The use of the regularization and the value of the Levenberg-Marquardt parameter at the last iteration different from zero determine an averaging kernel matrix different from the identity matrix. For each retrieved profile the averaging kernel matrix is provided in the outputs.

The IMK/IAA retrievals of temperature and trace gases from MIPAS reduced resolution (RR) UTLS-1 mode for 28/29 Nov 2005 compared with ECMWF analyses showed the following preliminary results (for details see papers in this proceeding):

Temperature	Good below 40 km, MIPAS colder above
H ₂ O	ECMWF too dry below 40 km, MIPAS too large above
O ₃	Considerable differences in large regions (attributed to problems in the ECMWF analyses)

The intercomparison of the RR UTLS-1 mode with Microwave Limb Sounder (MLS) data showed (for details see papers in this proceedings):

Temperature	Good up to 40 km, MIPAS bit colder above (exception: N-pole: MIPAS higher)
H ₂ O	Good up to 40 km, MIPAS too high above (except N-pole: MIPAS lower)
O ₃	Good everywhere (except N-pole: MIPAS lower)

HNO₃ MIPAS generally lower, but this due to a known 30% high bias of MLS Version 1.5.

3.4. MIPAS Conclusion

MIPAS products are generally of very good quality. The conclusions about the data quality as presented during the ACVE-2 are still valid [2]. The problem areas are well understood. Whilst emphasis has been placed on the validation of the FR products, enormous potential exists for the RR products, which have already undergone some initial validation, showing the high potential of the current operation of MIPAS.

The validation results for the operational products of MIPAS are summarised in Table 1. The estimates given are based on the differences with correlative data, and therefore some of these numbers will still include representation errors and uncertainties in the correlative data.

Table 1 MIPAS validation results

Parameter	Version 4.61/4.62		Comment
	Precision	Accuracy	
T	5 K	2 K *	
O3	<10 % *	< 10 % *	> 50 hPa
H2O	10-25%	10-20%	100-10 hPa
HNO3 Nitric Acid	< 10 %	<10 %	FTIR/ Bal./ Sat.(1-2 ppbv)
N2O Nitrous oxide	10%-28%	5%-30%	FTIR/ Balloon
CH4 Methane	5-18 %	5%-20%	FTIR/ Balloon
NO2 Nitrogen dioxide	5-15%	10-20%	25-40 km

* Explicitly within theoretical limits

4. GOMOS

4.1 GOMOS Level-1b Processing IPF 5.00 and GOPR6.0cf prototype

The current version of the processor contains important modification to the Level-1 processing. Level-2 processing algorithms also required important improvements. The improvements implemented in GOPR 6.0cf and IPF Version 5.00 are for the level 1b related to the correction for the Fast Photometer unfolding, background correction for Spectrometer B and a change in the Flat-Field Correction method.

4.2 GOMOS Level-2 Products IPF 5.00 and GOPR 6.0cf prototype

The changes in the level 2 processors are an improved optimisation of DOAS iterations, the correction of H RTP discrepancies, the implementation of a 2nd order polynomial for aerosol and the air fixed to ECMWF. Also the Orphal Cross sections for O₃ are now used and the GOMOS Cross sections for NO₂.

The following products taken under dark illumination conditions, except indicated otherwise, were validated (for details see papers in this proceeding):

O₃ (dark) *Bias estimation:*

Lidar <5%, 18-48 km
 Sonde <5%, 15-30 km
 ESABC no bias, 15-40 km
 MIPAS <5%, 50-80 km
 Osiris <5%, 20-45 km
 FMI -5% to 0% up to 30 km

Precision estimation:

Gomos-Gomos in accordance with reported error (except underestimation at 80 km and LS, overestimation 20-40 km)
 ESABC better than 10%
 Lidar-sonde depending on star Mv and T

O₃ (bright) *Bias estimation:*

MIPAS -50% (ESA),
 -50%-0% (IMK)
 Osiris -30% 35-65 km
 (mainly Polar)

Precision estimation:

No results

NO₂ *Bias estimation:*

ESA-BC no bias (<1%)

Precision estimation:

ESABC 20%

Gomos-Gomos in accordance with reported error

NO₃ *Bias estimation:*
 ESABC no conclusions
Precision estimation:
 Gomos-Gomos in accordance with reported error

Aerosol *Bias estimation:*
 ESABC good estimation at 500 nm for total content, no wavelength dependence
Precision estimation:
 No results

Temperature and Density
Bias estimation:
 NILU/EQUAL Best between 23-30 km, some sites -5 K and other sites 0 K. Not ready yet for scientific use

Precision estimation:
 Gomos-Gomos good and bad comparisons, good results for comparisons with the same type of star.

The following species were not presented/validated at ACVE-3: Aerosol, NO₃, H₂O, and O₂

4.3 GOMOS Conclusion

It was shown that the GOMOS instrument is producing global ozone values of high quality, especially suitable for monitoring purposes. The turbulence error in the 20-40 km range is overestimated. The limb flagging is too conservative. Very good, but also bad and inconclusive comparison cases were presented. It was recommended to revise the limb flagging to SZA. The validation teams are suggested to carefully consider meteorological condition for validation. The species flagging in product needs improvement and the disclaimer needs to be adapted to reflect the results presented.

The validation results for operational products of GOMOS are summarised in Table 2. The estimates given are based on the differences with correlative data, and therefore some of these numbers will still include representation errors and uncertainties in the correlative data.

Table 2 GOMOS validation results

IPF5.00/GOPR6.0cf			
Parameter	Precision	Accuracy	Comment
T	n.a.	<5 K	H RTP
O3	<10 %	< 5%*	Dark
O3	n.a.	50%	Bright
NO2	<20%	<1%*	Dark
NO3 Nitrate	30%	n.a.	Dark QWG estimate
Aerosols	N.a.	50%	Dark No systematic analysis, but good agreement with balloon

* Bias free

5. SCIAMACHY VALIDATION RESULTS

5.1 SCIAMACHY Level-1b Processing IPF v6.02

Level-1b processing has undergone significant improvement. Open issues were identified and understood. Recommendations were provided by the validation teams to ESA which are currently investigated and implemented in the operational processor. The current Level 1b Processor is IPF Version 6.02, which was activated at the D-PAC on 05 May 2006 and at PDHS-Kiruna, and PDHS-ESRIN on 07 June 2006. The major improvements are related to the parameterization of memory effect (Channel 1-5), the new correction for the IR non-linearity (Channel 6-8), the improved Key Data for radiometric calibration, the orbital leakage current for Channels 6-8 and the usage of the Envisat Restituted Attitude for improved pointing performance (off-line processor at D-PAC only). In the product the calibrated and un-calibrated solar spectrum are now included. The validation of the radiance and irradiance products resulted in:

Solar spectral irradiance

The agreement between SCIAMACHY irradiance and ground-based and satellite data is within a few percent in the region

from 400 up to 1000 nm Above 1000 nm the SCIAMACHY irradiances are up to 15% lower. Observed deviations in the UV with Kurucz spectra may be partly explained by (currently uncorrected) degradation of SCIAMACHY

Nadir UV-visible radiance

The absolute radiometric calibration for the sun-normalised radiance is improved. Deviations w.r.t. other satellites and models are less than a few % between 440-870 nm..

Nadir SWIR radiance

The better memory and non-linearity correction improved the nadir SWIR sun-normalised radiance. There is still an overestimation at 1600 nm compared with AATSR.

5.2 SCIAMACHY Level 2 Column Products Off-line V3.0

The current Level 2 Processor is the off-line processor Version 3.00, which was activated at D-PAC on 08 August 2006. The major improvements are related to the nadir UV/visible algorithm for ozone and NO₂, which is now based on the GDP (GOME Data Processor) Version 4.0. The nadir UV/visible algorithms for cloud-top height and cloud optical thickness are based on the SACURA algorithm; the fractional cloud cover is retrieved from PMD readings with the OCRA/GOME algorithm. For the limb UV/visible algorithm update the main improvements are expected in the stratospheric Ozone and NO₂ profiles. Also improvements are expected through the use of the Envisat Restituted Attitude information in the consolidated Level 1b.

Validation results for the following products have been presented (for details see papers in this proceedings):

- O₃ The quality of the OL 3.00 O₃ column is much better than the previous version. The values are consistent with ground-based and satellite data, with average deviations in the 0-2% range. The major problems of IPF 5.04 appear to have been solved. No dependences have been found to latitude, solar zenith angle and total ozone. In a few cases peaks of up to 7% have been found in the difference with other scientific retrievals. This has to be further investigated.
- NO₂ The quality of the OL 3.00 NO₂ column is much better than the previous version. The values are consistent with ground-based

data, with average deviations in the 0-10¹⁵ molecules/cm² range. The major problems of IPF 5.04 appear to have been solved. In a few cases differences of up to 8% have been found with other scientific retrievals. This has to be further investigated.

Clouds

The OL 3.00 cloud cover value correlates good to HICRU, and reasonable to FRESCO cloud cover. The RMS difference is of the order 0.1. Over desert and in the absence of clouds the OL 3.00 cloud cover can be overestimated up to 0.3. Differences between OL3.00 and FRESCO also occur over snow and ice covered regions. The OL 3.00 cloud cover is shown to be an *effective* cloud cover fraction, just like HICRU and FRESCO.

The OL3.00 cloud top height has an average difference to FRESCO cloud height of about 400m, but the spread in the difference is around 1.8 km. ISSCP cloud top height is used in 45% of the cases, the distribution of which differs strongly from that of SACURA, FRESCO and MERIS cloud heights.

The OL 3.00 Cloud Optical Thickness (COT) values are often unrealistically high.

Validation results have also been reported for the following column products using the non-operational (or scientific) processors validated (for details see papers in this proceedings):

CO

SRON

The error in the CO monthly mean is shown to be largely determined by the instrument noise error, which suggests that the CO retrieval precision almost reached its theoretical limit. For very low instrument noise error the difference to the model is about 5%.

CO

IFE v 0.6

A very good agreement was shown with MOPITT for 2004, and larger differences for 2003 and 2005, probably partly due to MOPITT having a different sensitivity to CO in the lower troposphere. First comparison with groundbased FTIR showed an improved correlation and lower scatter than for the previous version.

CH₄

IFE v 1.0

The results are significantly improved compared to v0.5 (no SZA bias). First comparisons with groundbased FTIR shows

an improved correlation and scatter. The negative bias and possibly too strong seasonality for some stations needs further investigation.

- CO₂ IFE v 1.0
The algorithm is significantly improved compared to v0.4 (no need for scaling). A high bias over deserts (e.g. Sahara) for high aerosol was found.
- CO₂ Leicester
CO₂ columns were shown to have a good correlation with surface CO₂ with deviations within 3%. A bias with respect to one FTIR (-4%) and TM3 (-2%) was presented.
- OCIO IFE
A reasonable agreement was found with ground-based observations and model. It was shown that small amounts of OCIO could be detected. A negative off-set for lower latitudes seems to be present. The accuracy approaches ~30%.
- HCHO IFE
The uncertainty for the monthly average of HCHO is estimated to be 4×10^{15} molec/cm². The retrieval of HCHO for SZA > 60° is still difficult.
- Glyoxal IFE
The global glyoxal (CHOCHO) maps of SCIAMACHY have strong similarities with HCHO distributions and also with NO₂ maps. A limited validation of SCIAMACHY glyoxal with MAX-DOAS measurements at Cabauw showed reasonable agreement.

5.3 SCIAMACHY Profile Products Off-line V3.0

The following profile products from the Off-line processor V3.0 have been validated (for details see the individual contributions in this proceedings):

- O₃ The quality of the OL 3.00 O₃ profile values is much improved compared to the previous version. The altitude registration is much better. The comparison to scientific retrievals is good, the comparison to ground-based, balloon and satellite data is reasonable. OL 3.00 O₃ profile values between 18 and 38 km are on average 0-20% smaller than correlative measurements, below 18 km they can be up to 20% larger. An apparent remaining altitude shift

between -1 and +2 km was reported by several presenters, but the magnitude and the dependence on latitude were not consistent. The unexpected behaviour at 40 km (reference height) will probably be adapted in a future processor upgrade.

- NO₂ The quality of the OL 3.00 NO₂ profile values is much improved compared to the previous version. The altitude registration is much better. The comparison to scientific retrievals is good, the comparison to ground-based, balloon and satellite data is reasonable. OL 3.00 NO₂ profile values between 16 and 42 km are on average 0-25% larger than correlative measurements. The agreement is better in Polar Regions and worse in the tropics. No apparent TH offset was detected.

Validation results have also been reported for the following profile products from the non-operational processors (for details see papers in this proceedings):

- O₃ IFE v 1.63 (~17-45km)
Validation results and average deviations are comparable to those from the OL 3.0; the IFE O₃ profiles behave better at 40km than the operational product.
- O₃ IFE mesospheric (~39-65km)
Mesospheric O₃ profiles are within 10-30% from MIPAS, and within 10% from RAM measurements.
- O₃ IFE occultation (~17-47km)
O₃ profile values from solar occultation are on average within 10% from other satellite data, for lunar occultation deviations can be up to 20%.
- NO₂ IFE Limb
Validation results and average deviations are comparable to OL 3.0 For altitudes less than 35km the results are comparable to HALOE. Compares better to balloon measurements than the OL3.0 results.
- NO₂ IFE Occultation
NO₂ profile values from solar and lunar occultation are on average within 20% from other satellite data.
- BrO IFE, Heidelberg/Mainz, SAO
The different scientific retrievals are mostly in agreement within the error bars Very good agreement with balloon-borne DOAS.

In the entire altitude range, the relative deviations are between -10% at the lower altitudes and 20% at higher altitudes.

NO₃ IFE lunar occultation
A good agreement was shown with a photochemical model up to 48 km.

OCIO Heidelberg/Mainz
A qualitative agreement with satellite, balloon and models was presented.

5.4 SCIAMACHY Conclusion

All the operational products have been largely improved with respect to previous versions. The altitude registration has improved. Scientific products keep improving, highlights:

- CO retrieval precision has almost reached theoretical limit (determined by instrument noise)
- CH₄: The potential of catching day-to-day variability of ~1% is demonstrated

The absolute calibration of the irradiance and the sun-normalised radiance has improved. A remaining (few %) offset in the latter above 700nm still exists. Several issues in both Level 1b and level 2 products have been identified to be solved and investigated before re-processing, see also section 6.4.

Table 3 SCIAMACHY column validation results

Parameter	OL Version 3.00		Comment
	Column		
	Precision	Accuracy	
O3	<1%	<3%	Significant improvement
NO2	2-10%	8-30%	Significant improvement
Cloud fraction	<0.12	0.1	
CTH	1.8km	<500m	

The validation results for operational products of SCIAMACHY are summarised in Table 3 and Table 4. The estimates given are based on the differences with a limited amount of correlative data, and therefore some

of these numbers will still include representation errors and uncertainties in the correlative data. The upcoming changes in the next release of the SCIAMACHY data processors will lead to more improved results.

Table 4 SCIAMACHY profile validation results

Parameter	OL Version 3.00		Comment
	Profile		
	Precision	Accuracy	
O3	<20%	<20%	
NO2	<25%	<30%	

6. Overall Conclusions and Recommendations

So far almost all operational and some of the non-operational products have been validated. For those which have been, and especially the core species such as Ozone which have been subject to ongoing validation, it has been determined that the Envisat products and validation measurements are now in closer agreement. These promising results are usually related to upgrades to the processors, which are in turn derived from a better understanding of the operation of the instruments in space.

in the course of the workshop the participants made the recommendations given below.

6.1 General Recommendations

- R1 To perform delta validation after each processor change
- R2 To verify/validate the operational data as well as the validation reference set
- R3 To acknowledge the validation activities with the corresponding support
- R4 To further optimise the validation reference set

6.2 MIPAS Recommendations

- MR1 The MIPAS FR data set must be reprocessed with the same version of the processor used for RR processing in order to generate a consistent dataset.
- MR2 The production of the MIPAS RR27 validation dataset should start as soon as possible.

6.3 GOMOS Recommendations

- GR1 Revise limb flagging to SZA
- GR2 Carefully consider the metrological conditions for validation
- GR3 Species flagging in product needs improvement
- GR4 Adapt disclaimer

6.4 SCIAMACHY Recommendations

The following recommendations are based on the outputs of the SCIAVALIG pre-validation meeting held in September 2006 and of the ACVE-3. The most important recommendations including those considered crucial to be performed before reprocessing can start are given below, for the remainder of the recommendations reference is made to the summary presentation as given during the ACVE-3 workshop [4]

O3 column

- SR1 To investigate the origin of the peaks in O₃ column differences between OL and scientific retrievals
- SR2 Change O₃ SCD to SCD after Ring correction

Clouds

- SR3 To fix the value of the cloud quality flag
- SR4 Extend use of SACURA down to 10% cloud cover
- SR5 To investigate the effect of cloud top height and optical thickness deviations on ozone columns
- SR6 To investigate if a correction factor should be applied to the reflectance prior to the cloud-top-height retrieval
- SR7 To investigate the cause of the difference of the OL COT with the SACURA scientific retrieval
- SR8 To investigate the FRESKO cloud-top-height differences between v5.04 and v6.02 for (almost) cloud-free scenes.

Profiles

- SR9 To investigate the remaining altitude shift in the O₃ profiles in the Arctic (Remark: recommendation to change roll offset, has to be investigated further)
- SR10 To investigate the unexpected O₃ profile behaviour at 40km (Remark: a change of reference height is foreseen)
- SR11 To investigate the apparent inconsistency between VMRs
- SR12 To investigate the cause of the different behaviour of the year 2003 (~35 km) for the profile differences

- SR13 To find the origin of the offset between OL NO₂ slant columns and the scientific retrievals (Remark: the problem is understood, a fixed offset is applied in OL)
- SR14 To investigate the cause of the large error bars in the NO₂ profile

Level 1b

- SR15 To find the origin of the difference between the ASM spectra provided in the Level 1b and those retrieved from level 0 (Remark: this is under investigation)
- SR16 To fix the dark current correction (sometimes not performed in off-line processing)

7. Acknowledgment

The authors would like to thank all the teams involved in the acquisition and analyses of the in-situ measurements, the Quality Working Groups and the teams involved in the Envisat data processing, the validation teams for the comparison of correlative data with Envisat data and the individual scientists, who had the difficult job to collect the information from the satellite data and the correlative measurements and to present a coherent result at the workshop.

The (financial) contributions of the different national and international agencies and organisations to the validation teams are acknowledged.

Ankie Piters is financially supported by the Netherlands Agency for Aerospace Programmes (NIVR).

8. References

1. [Pre-launch Workshop on the Atmospheric Chemistry Validation of Envisat \(ACVE\)](#), 16-18 May 2001, ESA-ESTEC, Noordwijk, The Netherlands.
2. Snoeij P., Fletcher P., Koopman R., Wursteisen P., Wehr T., Zehner C., Attema E., [Summary of the Atmospheric Chemistry Instrument Validation](#), Proceedings of the Second Workshop on the Atmospheric Chemistry Validation of ENVISAT (ACVE-2), 3-7 May 2004, ESA-ESRIN, Frascati, Italy, ESA SP-562, August 2004.
3. Fehr T., [The ENVISAT Atmospheric Chemistry Mission: status and performance](#), Atmospheric Science Conference, 8-12 May 2006, ESA ESRIN, Frascati, Italy.
4. Lambert J-C, Piters A., Fehr T., [Summary of the SCIAMACHY validation results](#), Third Workshop on the Atmospheric Chemistry Validation of ENVISAT (ACVE-3), 4-7 December 2006, ESA-ESRIN, Frascati, Italy.